INSTRUCTION BOOK

for

MODEL 365

SENSITIVE DC VOLT/AMMETER

QC CAL/CERT
PROCEDURES
GROUP COPY

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

INSTRUCTION BOOK

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SENSITIVE DC VOLT/AMMETER

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

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Each Ballantine Laboratories, Inc. instrument, or part thereof, is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

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FOR
MODEL 365 SENSITIVE DC VOLT/AMMETER

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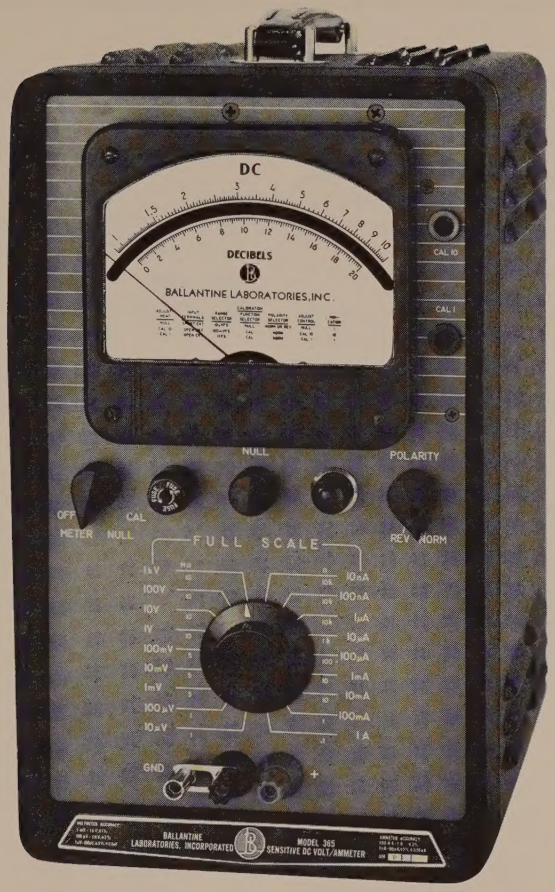


Fig. 1. Ballantine Model 365 Sensitive DC Volt/Ammeter, Portable Version

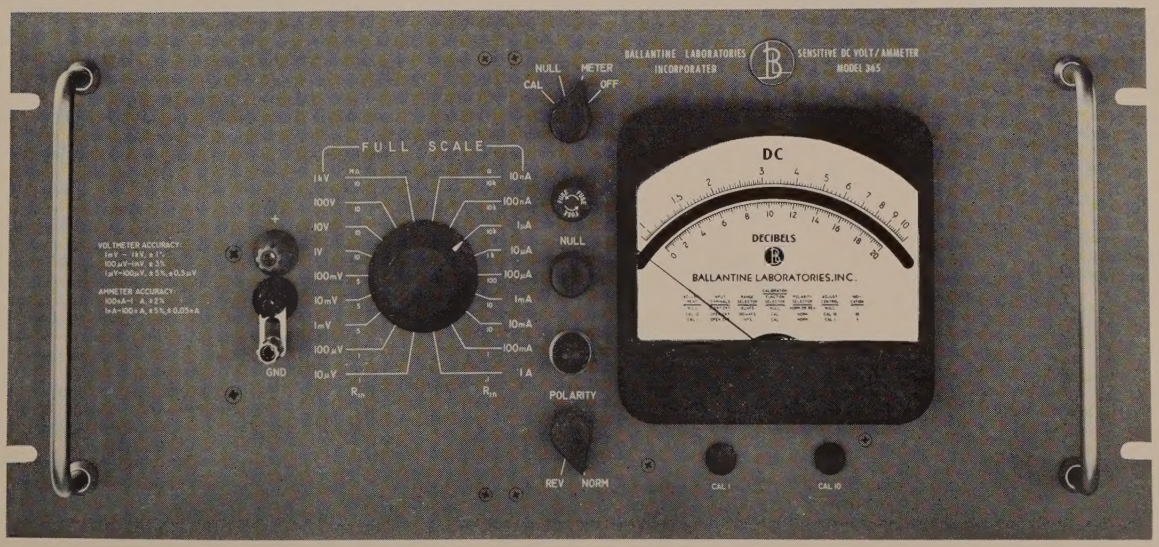


Fig. 2. Ballantine Model 365-S/2 Sensitive DC Volt/Ammeter, Rack Mounted

1. GENERAL INFORMATION

1.1 Features and Use

The Ballantine Model 365 is designed to measure the range of dc voltages and currents encountered in the electronics and related fields. Among its features are wide range, high accuracy, high input impedance, simple operation, internal calibration, and reliability.

A distinguishing feature of this instrument is its logarithmic voltage and current scale, which permits statements of accuracy in percentage of reading as opposed to percentage of full scale in the case of linear indicators. The use of a single, mirror-backed scale together with a single range-knob provides an unmatched simplicity of operation. A linear decibel scale permits the measurement of gains or power ratios directly in db without reference to slide rules or charts.

An internal standardizing source provides a simple, rapid check of the instrument accuracy without recourse to external equipment.

1.2 Some Applications of the Model 365

General dc voltage and current measurements in electronics and related fields.

Investigation of leakage current in capacitors, insulators, vacuum tubes, semiconductors.

Stability measurements of dc supplies either directly or differentially.

Sensitive null detector in dc bridge work.

Differential voltmeter.

High-gain, low-noise, dc amplifier.

1.3 Technical Characteristics

Voltmeter:

Range	Accuracy*	Input Impedance	
100 V —1 kV	1%	30 pF	10 MΩ ± 2%
10 V —100 V	1%	30 pF	10 MΩ ± 2%
1 V —10 V	1%	30 pF	10 MΩ ± 2%
100 mV—1 V	1%	30 pF	10 MΩ ± 2%
10 mV —100 mV	1%	35 pF	5 MΩ ± 3%
1 mV —10 mV	1%	35 pF	5 MΩ ± 3%
100 μV—1 mV	3%	35 pF	5 MΩ ± 3%
10 μV —100 μV	5% ±0.5 μV	35 pF	1 MΩ ±10%
1 μV —10 μV	5% ±0.5 μV	35 pF	1 MΩ ±10%

* of indication AT ANY POINT ON SCALE

Warmup Time—Usable after 30 seconds

Drift after 30 minutes 1 mV — 1 kV < 0.25%

1 μV — 1 mV < ±2 μV / day

Stability—All specifications maintained over range of 105 V to 125 V. Expected life before tube change or recalibration—2000 hrs.

Ammeter:

Range	Accuracy*	Input Resistance
100 mA—1A	2%	0.1 Ω
10 mA —100 mA	2%	1.0 Ω
1 mA —10 mA	2%	10.0 Ω
100 μA —1 mA	2%	10.0 Ω
10 μA —100 μA	2%	100.0 Ω
1 μA —10 μA	2%	1.0 kΩ
100 nA—1 μA	2%	10.0 kΩ
10 nA —100 nA	5% ±0.05 nA	10.0 kΩ
1 nA —10 nA	5% ±0.05 nA	10.0 kΩ

* of indication AT ANY POINT OF SCALE

Overloads—Voltage, 1 kV momentarily on 10 μV range. Current, 10 mA momentarily on 10 nA range.

Input Signal Isolation—Impedance between signal and panel grounds—R = 100 MΩ min, C = 0.1 μF, max potential = 500 V peak.

DC Amplifier:

Range	Gain	Output	Accuracy	Linearity	Noise*	Response Time
100 V —1 kV	—60 db	0.1-1 V	±1%	±0.5%	<30 mV	1.2 s
10 V —100 V	—40 db	0.1-1 V	±1%	±0.5%	<3 mV	1.2 s
1 V —10 V	—20 db	0.1-1 V	±1%	±0.5%	<300 μV	1.2 s
100 mV—1 V	0 db	0.1-1 V	±1%	±0.5%	<30 μV	1.2 s
10 mV —100 mV	20 db	0.1-1 V	±1%	±0.5%	<3 μV	1.2 s
1 mV —10 mV	40 db	0.1-1 V	±1%	±0.5%	<0.3 μV	1.2 s
100 μV—1 mV	60 db	0.1-1 V	±3%	±0.5%	<0.3 μV	1.2 s
10 μV —100 μV	80 db	0.1-1 V	±5% ±0.5 μV*	±5.0%	<0.3 μV**	2.0 s
1 μV —10 μV	100 db	0.1-1 V	±5% ±0.5 μV*	±5.0%	<0.3 μV**	2.0 s

* referred to input terminals ** with source resistance <100 kΩ

Drift—less than ±2 μV / day referred to input after 30 minute warmup.

Phase Shift—180° reference input.

AC Rejection—1.5 c ≅ 3 db; 60 c ≅ 45 db; 120 c ≅ 60 db.

Output Resistance— ≅ 1667 Ω.

Minimum Load Resistance—zero Ω, I max ≅ 600 μA.

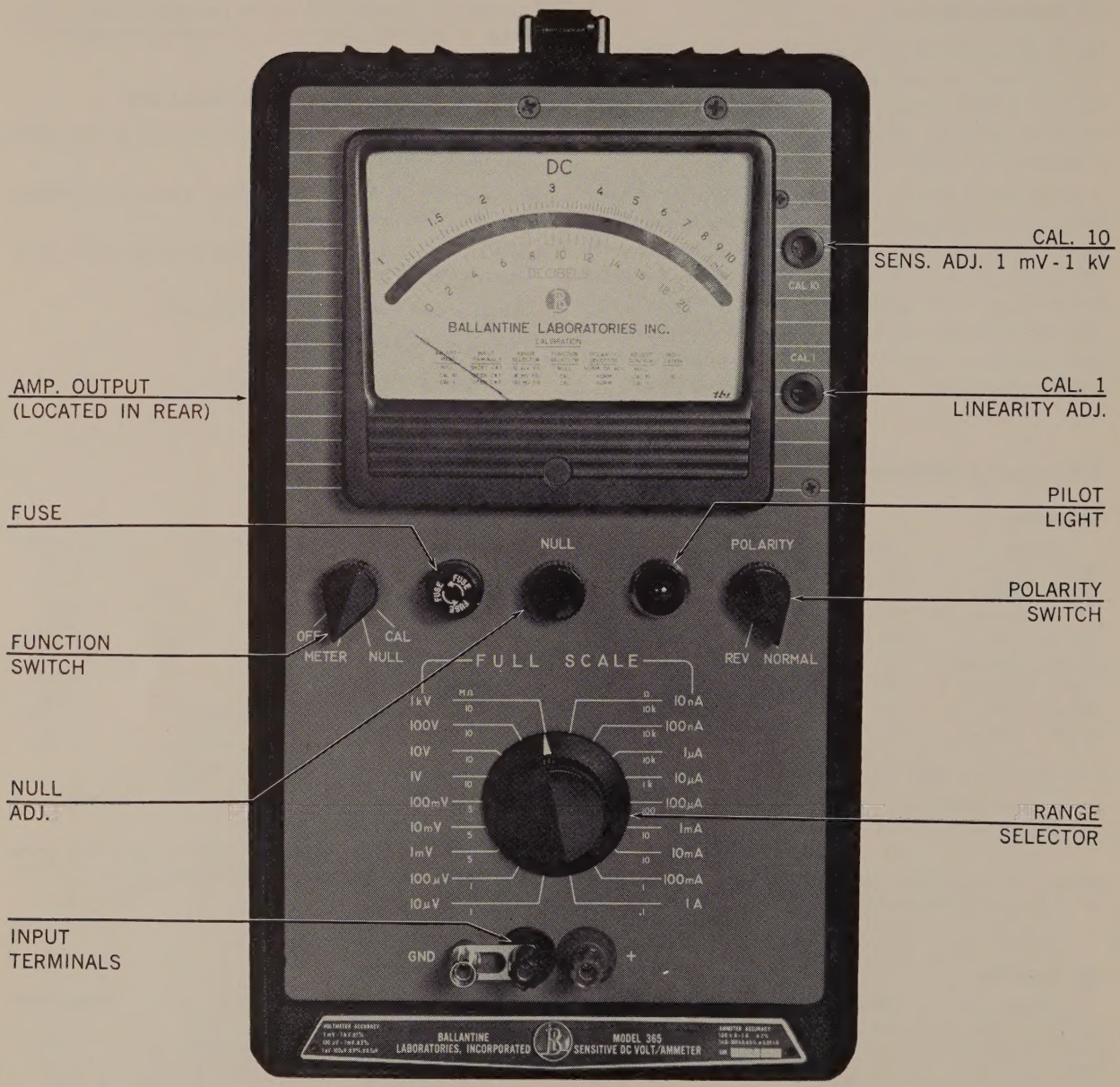


Fig. 3. Instrument Controls

Internal Calibration Standard

Type—Gaseous reference tube.

Stability—Better than 0.1% per 1000 hours operation.

Life Expectancy—30,000 hours.

Adjustment—Internal control permits compensation for aging effects.

Vacuum Tubes, Semiconductors, and Batteries

Tubes—2 Type 12AX7, 2 Type 6AU6, 1 Type 6X4, 1 Type OA2, 1 Type OB2WA, 1 Type 8228.

Semiconductors—2 Type 2N525, 5 Type 1N1692, 2 Type PG961A.

Batteries—1 Type RM1RT2.

Power Requirements

Voltage—105 V—125 V or 210 V—250 V.

Frequency—50 c—420 c.

Power—40 W.

Fuse—115 V—0.4 A Slo-Blo; 230 V—0.2 A Slo-Blo.

Mechanical Specifications

Color—Portable—gray panel, black wrinkle case. Rack—gray, other colors available on request.

Dimensions—Portable—13" high, 7½" wide, 10½" deep. Rack—8¾" high, 19" wide, 9½" deep.

Weight—Portable or Rack—16 lbs.

Shipping Weight—Portable 21 lbs.
Rack 33 lbs.

2. OPERATION

2.1 Function of Controls, Terminals, and Panel Adjustments (see Fig. 3)

Function Switch

OFF	Turns power off
METER	Selects voltmeter or ammeter mode of operation; amplifier output available at rear mounted connector
NULL	Selects NULL indicator mode of operation and permits proper adjustment of NULL control; amplifier output available at rear mounted connector
CAL	Permits check of instrument calibration; +10 mV applied to open circuit input terminals

Range Selector

FULL SCALE	Selects the voltage or current range desired; changes amplifier gain in steps of 20 db

POLARITY Switch

NORM	Positive polarity at red binding post gives up scale indications; negative polarity gives no indication
REV	Negative polarity at red binding post gives up scale indications
NULL	Permits residual and drift cancellation, necessary for accurate measurements on most sensitive ranges
CAL 10	Adjusts the overall sensitivity of the instrument for the 1 mV to 1 kV range
CAL 1	Adjusts the linearity of the instrument

Terminals and Connectors (see Fig. 3 for locations)

INPUT	The red (+) and black (−) binding posts accept the dc input. The ground binding post is permanently tied to the instrument case, panel, and power cord ground lead; it may be connected to the black (−) binding post with a grounding link. The polarities designated above apply for the NORM position of the POLARITY switch.
AMP OUTPUT	Type BNC connector provides amplified, single-ended, dc output

2.2 Power Connection

The voltmeter is supplied ready to operate on 105 V - 125 V, 50 c - 420 c, or 210 V - 250 V, 50 c - 420 c power, as indicated on the decal located adjacent to the power cord. If it is desired to convert the instrument for 230 V operation or vice versa, complete instructions may be found in Section 4.1.2.

2.2.1 Warmup Period

After connecting the power cord to a suitable source, move the function switch to the METER position. The pilot lamp should glow.

The instrument is usable after approximately 30 seconds. For accurate measurements on the most sensitive ranges allow a warmup of at least 30 minutes, and adjust the NULL control in accordance with Section 2.3.1.

NOTE: FOR GREATEST ACCURACY AND FOR LONGEST INSTRUMENT LIFE, DO NOT PLACE INSTRUMENT CLOSE TO SOURCES OF HEAT. FREE AIR FLOW AROUND ALL SIDES OF THE INSTRUMENT IS DESIRABLE.

2.3 NULL Adjustment

2.3.1 Voltage Measurements Below 1 mV

The function of the NULL adjustment is to "zero" or cancel out small residual voltages in the input system of the voltmeter. Since these residuals tend to be a

function of time and temperature, when making low level measurements (below 1 mV) this adjustment should be made and checked frequently for greatest accuracy.

To make the NULL adujstment, carry out the following procedure:

a. Short the input terminals with a piece of copper wire, or place a resistor equal in value to the source resistance of the unknown voltage across the input terminals (see note below). Allow a short period for any heat generated in handling of leads and binding posts to dissipate.

   NOTE: If a resistor is employed in this process care should be taken to ensure that it in itself is not a source of dc. Some of the alloys employed in wirewound resistors have rather large thermal potentials against copper. Resistors using Evanohm and manganin alloys are generally satisfactory.

b. Set the range selector to the 10 μV position.

c. Set the function switch to the NULL position.

d. Adjust the NULL control for an indication of 1 on the meter. There will be considerable fluctuation in the indication at this point on this range. Indication fluctuations of up to ± 0.3 μV may be considered normal, and are caused by noise, thermal potentials, etc., in the input circuits of the instrument. This fluctuation noise represents the major uncertainty on this range and its effect becomes proportionately less as the input level is raised.

e. Return the function switch to the METER position.

2.3.2 Voltage Measurements Above 1 mV

For measurements in this region it is necessary only to set the NULL control to its mid position to obtain indications within specified accuracy. Were it not for the fact that the instrument measures at lower levels, it would have been possible to omit the NULL control.

2.3.3 Current Measurements Below 100 nA

To make the NULL adjustment for measurements in this region, proceed as follows:

a. Open circuit the input terminals.

b. Set the function switch to NULL.

c. Set the range selector to the 10 nA position.

d. Adjust the NULL control for an indication of 1. There will be a certain amount of fluctuation in the indication at this point. Fluctuations of up to 3% (0.97 to 1.03) may be considered normal and will not place the instrument outside of specification. A discussion of the factors and effects of this fluctuation is included in Section 2.3.1.d.

The adjustment of the NULL on this range satisfies all other current ranges, and will hold for extended periods of time, except where there are large variations in environmental conditions such as temperature, humidity, etc.

2.3.4 Current Measurements Above 100 nA

For measurements in this region it is necessary only to set the NULL control to its mid position to obtain indication within specified accuracy.

2.4 CAL Check

The stability of this instrument is such that it will maintain performance within specifications over extended periods of time and operation. However, to provide the user with a simple, rapid calibration check without recourse to external equipment or a standards laboratory, a stable, reliable, internal dc source, as well as panel controls for adjusting the sensitivity and linearity of the instrument, has been provided. To check the calibration, proceed as follows:

a. Check the NULL adjustment as outlined in Section 2.3. For most measurements (1 mV to 1 kV) it is simply necessary to set the NULL control to mid-position.

b. Open-circuit the input terminals.

c. Set the function switch to CAL.

d. Set the range selector to 10 mV.

e. The meter should now indicate precisely 10. If it does not, adjust to precisely 10 by means of the CAL 10 control located on the front panel adjacent to the meter case (see Fig. 3).

f. Set the range selector to 100 mV.

g. The meter should now indicate precisely 1. If it does not, adjust to precisely 1 by means of the CAL 1 control located on the front panel adjacent to the meter case (see Fig. 3).

h. Repeat steps d through g if necessary. There is little interaction between these controls unless the CAL 1 is initially greatly out of adjustment.

i. Return the function switch to the METER position and proceed with measurements.

The above procedure checks and adjusts the calibration on the 1 mV through 1 kV ranges and, indirectly, the 100 nA through 1 A ranges, and does not directly affect the most sensitive ranges. However, large changes in the sensitivity of these ranges would be reflected as changes in sensitivity in the 1 mV through 1 kV region. A procedure for checking and adjusting the calibration of the 10 μV and 100 μV ranges is covered under Section 4.3.2.

2.5 Voltage Measurement

2.5.1 Measurements from 1 mV to 1 kV

To make voltage measurements, proceed as follows:

a. Make the NULL adjustment as outlined in Section 2.3.2.

b. Set the function switch to METER.

c. Set the range selector to a range known to include the voltage to be measured; if the latter is unknown, set the range selector to 1 kV.

d. Connect the voltage to be measured to the input terminals, observing polarity if known.

e. Set the POLARITY switch to NORM.

f. Reduce the setting of the range selector for an on-scale indication, reversing the POLARITY switch on each range if the polarity is unknown.

g. The indication of the meter together with the position of the range selector gives the value of the voltages at the input terminals.

2.5.2 Measurements from 1 μV to 1 mV

The procedure for low level measurements is the same as outlined in Section 2.5.1 with the addition of a few precautions and notes as follows:

a. Check the NULL adjustment as outlined in Section 2.3.1.

b. With high source resistances, guard against excessive spurious pickup by employing shielding if necessary.

c. Be aware that thermal potentials may be generated wherever dissimilar metals come in contact and temperature gradients exist.

d. Be aware of electrolytic potentials existing in parasitic form. Following are examples of the potentials developed between a bare copper wire and a tinned copper wire (with a 100 kΩ load) immersed in some common solvents.

Solvent	EMF
Faucet water	30 - 50 mV
Denatured alcohol	20 mV
Butyl acetate	25 μV

2.6 Current Measurement

To measure current, proceed as follows:

a. Make the NULL adjustment as outlined in Sections 2.3.3 and 2.3.4.

b. Set the function switch to METER.

c. Set the POLARITY switch to NORM.

d. Set the range selector to a range which includes the current to be measured; if the latter is unknown, set the range selector to 1 A.

e. Connect the current to be measured to the input terminals, observing polarity if known.

f. Reduce the setting of the range selector for an on-scale indication, reversing the POLARITY switch on each range if the polarity is unknown.

g. The indication of the meter together with the position of the range selector gives the value of the current at the input terminals.

2.7 Use as Amplifier

To operate this instrument as an amplifier, proceed as follows:

a. Connect the signal to be amplified to the input terminals.

b. Set the function switch to METER.

c. Set the range selector for an on-scale indication.

d. The output signal is available at the output jack located on the rear of the instrument.

The dc output is single ended, and reversed in phase from the input signal. The output resistance is approximately 1667 ohms, while the load resistance may be as low as zero ohms, in which case a current of 600 μA (corresponding to full scale indication) is available. It should be noted that with low load resistances on the dc output there will be a change in meter indication as follows:

Range	Load Resistance	
	1 kΩ	0 Ω
10 μV - 100 μV	≅ 2.5%	≅ 5%
1 mV - 1 kV	≅ 0.25%	≅ 0.5%

For complete specifications on gain, accuracy, linearity, noise, etc., see Section 1.3, Technical Characteristics.

2.8 Ungrounded or Differential Measurements

Ungrounded or differential measurements may be made with the meter by observing the following procedure:

a. Disconnect the ground link between the ground and black binding posts.

b. Apply the voltage or current to be measured to the red and black binding posts.

c. Follow the procedures outlined under Sections 2.3 through 2.6.

d. Do not allow more than 500 volts peak between the ground and black binding posts.

e. Be aware of the possibility of currents of line frequency flowing in the impedance of either or both sources if they are also line operated. Where circumstances permit, the effects of such a current may be eliminated or reduced by shunting the dc sources with capacitive reactances (at line frequency) small in comparison with the source resistances.

2.9 Overload Considerations

The design of this meter is such that it will withstand rather severe overloads without damage. Thus **momentary** overloads of 1000 volts on the most sensitive range (10 μV) cause no harm. It is recommended, however, that any overload be removed rather promptly, to avoid damage to components in the input section of the instrument. Table I is a listing of maximum overloads of both a sustained as well as a momentary nature for each range.

TABLE I

MAXIMUM OVERLOADS		
Range	**Sustained**	**Momentary**
10 μV	100 V	1000 V
100 μV	100 V	1000 V
1 mV	100 V	1000 V
10 mV	100 V	1000 V
100 mV	100 V	1000 V
1 V	1000 V	1000 V
10 V	1000 V	1000 V
100 V	1000 V	1000 V
1 kV	1000 V	1000 V
10 nA	5 mA	10 mA
100 nA	5 mA	10 mA
1 μA	5 mA	10 mA
10 μA	20 mA	30 mA
100 μA	50 mA	100 mA
1 mA	200 mA	300 mA
10 mA	200 mA	300 mA
100 mA	500 mA	700 mA
1 A	1 A	2 A

2.10 Input Impedance

The input impedance of this instrument may be represented as a parallel combination of resistance and capacitance. The capacitive component is essentially constant from range to range, while the resistive component is one of a number of values dependent upon the range in use. The panel marking for the range selector indicates the input resistance as well as the voltage or current range. Table II is a listing of input capacitance and resistance vs. range.

2.11 NULL Operation and Approximate Measurements from 0 to 1 μV, and 0 to 1 nA

In bridge, potentiometric, and similar work, a sensitive null detector is usually employed to indicate zero voltage or current. Since the logarithmic scale has no zero, a means is provided to present the equivalent of zero. In this instrument when the function switch is set to NULL, the indicator is biased to bring the pointer to 1 on the scale in the absence of input signal; this point now corresponds to zero voltage or current at the input terminal on any range.

TABLE II

INPUT IMPEDANCE vs. RANGE		
Range	**Resistance**	**Capacitance**
10 μV	1 MΩ	35 pF
100 μV	1 MΩ	35 pF
1 mV	5 MΩ	35 pF
10 mV	5 MΩ	35 pF
100 mV	5 MΩ	35 pF
1 V	10 MΩ	30 pF
10 V	10 MΩ	30 pF
100 V	10 MΩ	30 pF
1 kV	10 MΩ	30 pF
10 nA	10 kΩ	.....
100 nA	10 kΩ	.....
1 μA	10 kΩ	.....
10 μA	1 kΩ	.....
100 μA	100 Ω	.....
1 mA	10 Ω	.....
10 mA	10 Ω	.....
100 mA	1 Ω	.....
1 A	0.1 Ω	.....

On the most sensitive ranges the pointer may not indicate 1 unless properly adjusted with the NULL control as outlined in Sections 2.3.1, 2.3.2, 2.3.3, and 2.3.4. When properly adjusted on the most sensitive ranges, the null resolution becomes a fraction of a microvolt or a nanoampere.

By this means it is also possible to make approximate measurements of potentials in the range of 0 to 1 μV and currents in the range of 0 to 1 nA. It is simply necessary to:

a. Set the function switch to NULL and adjust the NULL control as outlined in Sections 2.3.1 and 2.3.3.

b. Connect the voltage or current to the input terminals alllowing sufficient time for any heat generated in connections to dissipate.

c. Note the meter indication and subtract 1 μV (or 1 nA as the case may be) for the approximate value of the unknown.

2.12 Effect of AC Signals

A filter has been included in the input to eliminate or reduce effects caused by spurious or unwanted ac signals that may be present with the dc being measured.

Low frequency components of line voltage frequency and its harmonics may be as large as 100 times the dc level before causing any appreciable degradation of accuracy.

Since the input chopper or modulator operates at a frequency of 94 c ±5%, an ac signal of 94 c or close to 94 c will cause errors in indication dependent upon its magnitude, phase, etc. Internal filtering sufficient to completely eliminate this effect would make the response time prohibitively long, de-

grading overall performance. However, the likelihood of encountering 94 c signals in dc measurements is very small. In any event such a signal may always be reduced in a simple external filter.

2.13 Possible Error Sources

Some causes of error or measurement difficulties are listed below:

2.13.1 Indicator Remains in Extreme Left Position

This condition may be caused by:

a. Power cord disconnected.

b. Function switch in OFF position.

c. Fuse open.

d. Input voltage lower than range selector position.

e. POLARITY switch in wrong position for input polarity.

2.13.2 Indication High

If the indication is high and remains on scale when the next higher range is selected, in all probability the function switch has been left in the NULL position; return it to the METER position.

2.13.3 Indicator Beats or Flutters

This condition may be caused by:

a. Large spurious ac signal (probably low frequency or near 94 c) present along with the dc signal (see Section 2.12).

b. Instrument being operated in strong magnetic field such as exists adjacent to certain types of power transformers and line voltage regulators.

c. Noisy or unstable input signal.

3. CIRCUIT DESCRIPTION

The basic circuitry of this instrument is shown in Fig. 4 Simplified Schematic, while a complete schematic Fig. 7 is located at the end of this manual.

Tracing the signal, the dc input is attenuated as necessary, converted to 94 c ac by means of a mechanical modulator or chopper, amplified in the input amplifier, attenuated again as necessary, amplified further in the output amplifier, synchronously demodulated, passed through a meter to provide indication, and through a resistor to provide an amplified dc output.

Since the basic sensitivity of this instrument is 10 μV full scale, it is necessary to either change this basic sensitivity or employ attenuation for voltages higher than 10 μV; both methods are employed. Table III shows the total attenuation vs. range selector setting as well as the points where the attenuation occurs.

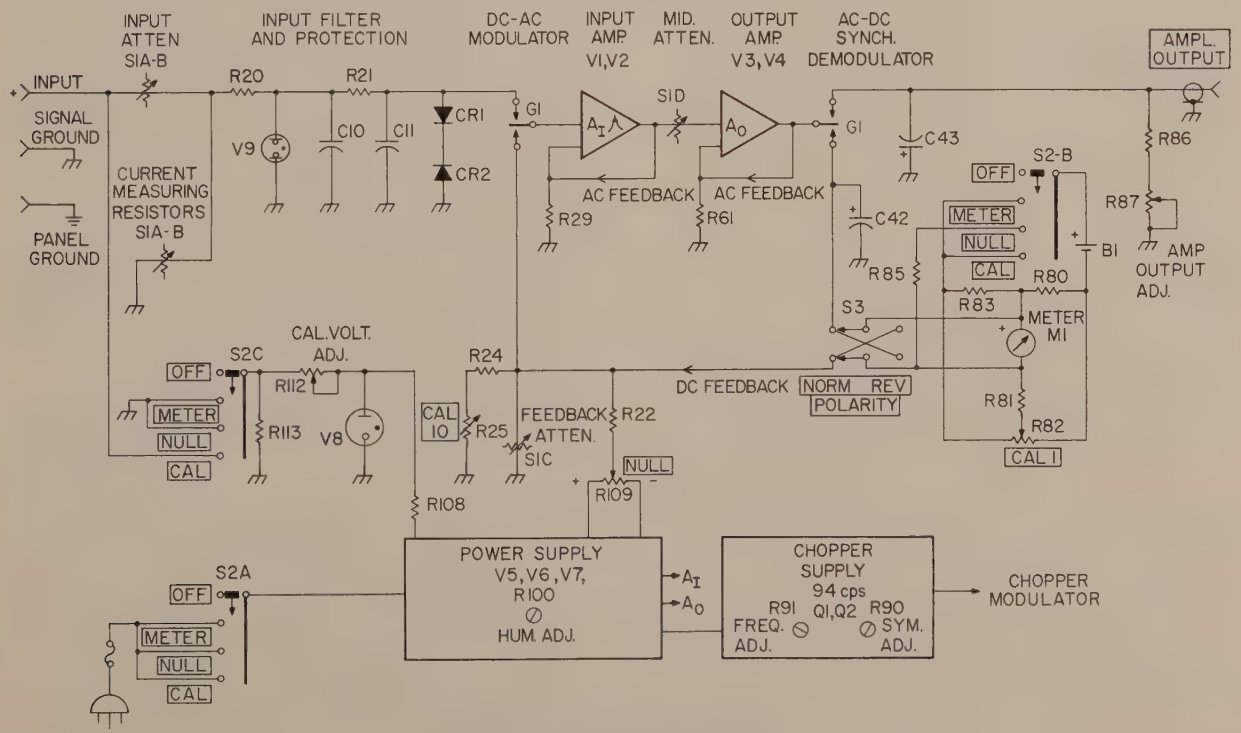


Fig. 4. Simplified Schematic

TABLE III

ATTENUATION vs. RANGE SELECTOR SETTING

Range	Input Attenuation	Loop Feedback Attenuation	Mid-Section Attenuation	Total Attenuation
10 μV	0 db	0 db	0 db	0 db
100 μV	0 db	0 db	20 db	20 db
1 mV	0 db	20 db	20 db	40 db
10 mV	0 db	20 db	40 db	60 db
100 mV	0 db	20 db	60 db	80 db
1 V	40 db	20 db	40 db	100 db
10 V	40 db	20 db	60 db	120 db
100 V	60 db	20 db	60 db	140 db
1 kV	80 db	20 db	60 db	160 db

The following sections 3.1 through 3.9 discuss in some detail the basic units, their circuitry, and in some instances components used.

3.1 Input Attenuator

The input attenuator provides attenuation of 0, 40, 60, and 80 db (see Table III), and is of the simple, resistive-divider type. The resistors used are a hermetically-sealed, deposited-carbon type of advanced design, having a stability approaching that of wirewound types. Initially the resistor values are matched to within $\pm 0.1\%$, while their temperature coefficients are matched to 30 ppm. The result is a stable, accurate attenuator having long life and capable of withstanding severe environmental conditions.

On the current ranges of the instrument the input attenuator selects a current measuring resistor as well as the appropriate attenuation. The current resistors are of the deposited-carbon type except for the two lowest values (1 and 0.1 ohms) which are wirewound units.

3.2 Input Filter and Protective Devices

A two-section, low pass, rc filter is used to reduce the effects of spurious or superimposed ac signals. The 3 db point is approximately 1.5 c, with 60 c down approximately 45 db, and 120 c down approximately 60 db. With this order of rejection, line frequency signals 100 times the amplitude of the dc signal cause no degradation of specifications.

To protect the input filter capacitors against accidental overloads, a neon, gaseous discharge tube is used. To further protect the chopper against overloads a pair of zener diodes in back-to-back configuration is used. The protection afforded is such that **momentary** overloads of up to 1 kV on the most sensitive range may be imposed without damage. It should be noted, however, that with 1 kV applied on the most sensitive range R20, rated at 2 W, will be dissipating approximately 6 W.

It is imperative therefore to remove large overloads as soon as possible to prevent permanent damage to this resistor.

3.3 DC to AC Modulator

To convert the dc input to ac, this instrument employs a mechanical modulator or chopper, which is still regarded as the best choice for this purpose, particularly where low levels are involved. Of the various conversion means available the mechanical modulator displays:

a. The highest conversion efficiency.
b. The lowest residual noise level.
c. The lowest residual dc.
d. The lowest dc drift.

To avoid dependence on power supply frequency and to reduce the effects of power supply hum the chopper operates at a frequency of 94 c; hence the signal frequency after conversion is 94 c. The power supply frequency is limited only by other considerations (transformer, ripple, etc.) and may be any of the common supply frequencies in the range of 50 c to 420 c.

The input chopper is of the single pole, double throw type using gold alloy, twin contacts, designed especially for low level operation.

3.4 Input Amplifier

AC signal (94 cps) from the input chopper is sent to the input amplifier which has a gain of approximately 1,350. The amplifier uses two triodes and a pentode with overall feedback stabilization of 26 db or greater. To reduce noise the bandwidth is severely restricted by making the plate load of the last stage a parallel resonant circuit tuned to the signal frequency. To further reduce noise the input triodes are operated semi-starved, while metal film and deposited carbon type resistors are used at all critical points. The heaters of the input triode are operated on dc (rectified and filtered ac) while the plate and screen supply for all three tubes is stabilized by a gaseous regulator tube.

3.5 Mid-Section Attenuator

Signal from the input amplifier is sent to the output amplifier via the mid-section attenuator. This attenuator, in addition to providing range switching between the two most sensitive ranges, permits the input signal-to-noise ratio to increase whenever it introduces attenuation.

This attenuator is also of the simple resistive divider type and employs deposited carbon resistors. The values of these resistors directly affect the accuracy of the instrument on only one range, the 100 μV; on all subsequent ranges the input attenuator and dc loop feedback primarily determine the sensitivity. The dc feedback loop effectively reduces any changes occurring in the mid-section attenuator by a factor of 10. Hence the choice of deposited carbon resistors for this attenuator is a logical one.

3.6 Output Amplifier

Signal from the mid-section attenuator is further amplified in the output amplifier, which in configuration is very similar to the input amplifier. Two triodes and a pentode are

operated with overall feedback stabilization of 26 db. Again in the interest of low noise, the triodes are operated semi-starved, while the plate and screen potential are derived from a gaseous regulator tube.

In contrast to the input amplifier where all three tubes are operated to provide voltage gain, in this amplifier the output tube serves to convert voltage to current.

3.7 AC to DC Demodulator, Meter, and DC Output Circuits

AC current from the output amplifier is passed to a synchronous demodulator which in turn supplies dc current to drive the indicating meter, to derive the loop feedback and dc output voltages. Synchronous demodulation is used because of its inherent noise rejection capability and because a properly phased relationship is necessary for dc loop feedback.

The demodulator used is of the mechanical type contained with, but electrically isolated from, the input modulator. Again the unit is a single-pole, double-throw type, employing twin contacts of a platinum-rhodium alloy. All contacts are protected against severe overloads by gaseous discharge tubes.

One phase of the demodulated current is passed through the indicator and thence to ground via the feedback resistors. The indicator has shaped pole pieces to provide a logarithmic voltage scale and linear decibel scale. C42 reduces the effects of ripple and transients in the demodulated output. A mercury cell (B1) provides a small correction current for adjusting the meter at 1 on the scale (CAL 1), and also provides a bias current in the NULL function causing the meter to indicate 1 in the absence of signal. The POLARITY switch reverses the direction of the current through the meter when this is necessary.

Demodulated current passing through resistors R11, R12, and R13 (dependent on range selector setting) provides a feedback voltage in the input circuit. Since the sensitivity of the instrument on all except the 10 μV and 100 μV ranges is directly affected by these resistors, wirewound units initially matched to 0.1% are used. The sensitivity of the instrument on all except the 10 μV and 100 μV ranges is adjusted by a shunt across the feedback resistors. R23, a calibration item, provides a coarse adjustment while R25, a potentiometer (CAL 10) provides a fine adjustment. A second current which may be zero or of either polarity is also sent through the feedback resistor to provide a means (NULL control) of cancelling residual potentials in the input circuit.

Demodulated current, opposite in phase to that through the meter, is passed to ground via R86 and R87; the voltage derived across these is used as the dc output. Capacitor C43 reduces ripple and transients in this output. Potentiometer R87 permits adjustment of the dc output to 1 V to correspond to full scale indication on the meter. Thus a voltage of 0.1 to 1.0 volts is obtained for each decade range of the instrument. The accuracy and linearity of this voltage is a function of the range in use and is presented in Section 1.3 Technical Characteristics. The output voltage undergoes a phase reversal in the instrument and is thus reversed from the input; operation of the POLARITY switch in no way affects this.

3.8 Stabilized Calibration Source

The internal calibration voltage is derived from a resistive divider across a gaseous reference tube which receives its current from another gaseous regulator tube. The reference tube used (V8, ZZ1000/8228) is of advanced design having a special electrode configuration, a neon-argon gas mixture, and special getter design. Checks indicate that this tube has an expected lifetime of greater than 30,000 hours, a stability of within 0.05% per 1,000 hours of operation, and a temperature coefficient of less than 0.004%/°C. Resistor R112 provides for an adjustment of the calibration voltage should this become necessary.

3.9 Power Supply

All necessary operating potentials are derived from a line-operated power supply. High potentials for plates and screens are obtained from rectified ac, rc filtered and gaseous-tube stabilized. All tube heaters except those of V1 are operated on ac balanced with respect to ground. The heater of V1 is operated on rectified ac with rc filtering. Potentiometer R100 across this dc supply is adjusted to provide minimum hum in the input stages.

The mechanical modulator-demodulator is driven by a 94 c bistable, multivibrator using two rugged transistors which convert 12 V dc to square wave ac. Since the transistors operate only as switches they dissipate very little power, leading to low internal temperature and long life. R91 permits a small adjustment of operating frequency, while R90 provides for an adjustment of symmetry. It should be noted that if the drive supply (7 pin connector on top of chopper unit) is removed with the power on, and then reconnected, the transistors will be saturated and the unit will not restart until the power is interrupted and reapplied. There will be no damage done.

4. MAINTENANCE

The Model 365 has been designed to provide a long, trouble-free life. To this end all tubes and components are operated well below their maximum ratings. Checks conducted at Ballantine Laboratories, Inc. indicate that at least several thousand hours of operation may be expected before there is any need to replace tubes or modulator, or make adjustments.

The purpose of this section is to provide procedures for checking performance and correcting if necessary. The Periodic Checks (Section 4.2) will not only check performance, but may help detect incipient failure and assure instrument accuracy until the next periodic check.

4.1 General Instructions

4.1.1 Fuse and Pilot Lamp Replacement

The fuse is of the Slo-Blo type and is rated at 0.4 A for 115 V operation and 0.2 A for 230 V operation. The fuse holder is of the extractor post type and is located on the front panel.

The pilot lamp, Type 1815, is accessible by unscrewing the red plastic cap located on the front panel.

4.1.2 Line Voltage Conversion

It is possible to operate the Model 365 from either a 115 V or 230 V line supply. The line voltage for which the instrument is connected on leaving the factory is indicated on a decal located adjacent to the line cord.

At the rear of the instrument on the power cord receptacle bracket are three terminals marked 1, 2, and 3. The power transformer connections are as follows:

Terminal	Power Transformer Leads	
	115 V	230 V
1	Black, Black-Red	Black
2	No Connection	Black-Yellow, Black-Red
3	Black-Yellow, Black-Green	Black-Green

4.2 Periodic Checks

4.2.1 Equipment Required

a. A stable, accurate, low-resistance source of dc covering a range of 100 μV to 100 V. The Ballantine Model 421 is recommended.

b. A stable, accurate, dc indicator covering at least the range of 0.1 V to 500 V.

c. A sensitive, vacuum tube voltmeter, covering at least the range of 50 c to 120 c and if possible frequency selective at 120 c.

4.2.2 2,000 Hours Operation Check

At the end of each 2,000 hours of operation it is recommended that the checks outlined in the following sections be made:

4.3.1 Scale Adjustment
4.3.2 Sensitivity Adjustment
4.3.3 NULL Current
4.3.4 NULL Control
4.3.5 Noise
4.3.6 Range Switching
4.3.7 DC Output Adjustment
4.3.8 Stability with Line Voltage
4.3.9 Calibration Source

4.2.3 4,000 Hours Operation Check

At the end of each 4,000 hours of operation it is recommended that all vacuum tubes be checked on a reliable tester, and those indicating low gm, grid current, shorts, etc., be replaced. In addition, the checks outlined in the following sections should be made:

4.3.1 Scale Adjustment
4.3.2 Sensitivity Adjustment
4.3.3 NULL Current
4.3.4 NULL Control
4.3.5 Noise
4.3.6 Range Switching
4.3.7 DC Output Adjustment
4.3.8 Stability with Line Voltage
4.3.9 Calibration Source
4.3.11 Chopper Supply Adjustments
4.3.13 Ammeter Accuracy

4.3 Performance and Maintenance Checks

4.3.1 Scale Adjustment

To check the scale adjustment, proceed as follows:

a. Set the Model 365 range selector to 100 mV.

b. Connect a stable, low-resistance source of dc to the input of the Model 365.

c. Adjust the amplitude of the dc source for an indication of precisely 10 on the Model 365.

d. Reduce the output of the dc source by the precise factor of 10.

e. Note the indication of the Model 365. If it is not precisely 1, adjust for this by means of R82 (CAL 1) control located on the front panel.

f. Recheck and repeat steps c through e as necessary.

4.3.2 Sensitivity Adjustment

4.3.2.1 10 μV and 100 μV ranges

To check the sensitivity of these ranges, proceed as follows:

a. Check the NULL adjustment as outlined in Section 2.3.1.

b. Set the range selector to the 100 μV range.

c. Connect a stable, accurate, low-resistance source of 100 μV dc to the input of the Model 365. The Model 365 should indicate 100 μV within $\pm 2\%$.

If the error is greater than $\pm 2\%$, it may be corrected by replacing R64 (see Fig. 6) with the value required.

4.3.2.2 1 mV to 1 kV ranges

To check the sensitivity of these ranges, proceed as follows:

a. Make the check outlined in Section 4.3.2.1, and correct as necessary.

b. Set the Model 365 range selector to 100 mV.

c. Connect a stable, accurate, low-resistance source of dc to the input of the Model 365.

d. Set the dc source to 100, 90, 80, 70, 60, 50, 40, 30, 20, 15, and 10 mV, noting both the magnitudes and signs of any errors in the indication of the Model 365.

e. Readjust CAL 10 located on the front panel (see Fig. 1) so that the maximum positive and negative errors are equal in magnitude.

R25 (CAL 10) provides only a limited range of adjustment which should be large enough to compensate for any normal aging effects in the instrument. R23 (see Fig. 5) provides a means for making larger adjustments; however, the need to change this value probably indicates that tube or other component replacement is necessary.

4.3.3 NULL Current

To check the NULL current, proceed as follows:

a. With zero input set the range selector to the 1 kV range.

b. Set the function switch to the NULL position.

c. The meter indication should be 1 $\pm$2%.

There are no controls for adjusting the NULL current. R85 in this circuit may be changed to correct the current; however, the necessity to change this value probably indicates that B1, the 1.35 V mercury cell, requires replacement. To replace B1 (see Fig. 5) loosen the two set screws securing the cell, replace with a fresh unit and retighten the set screws.

NOTE: DO NOT DISPOSE OF MERCURY CELLS BY BURNING. THE CELL IS A SEALED SYSTEM AND MAY EXPLODE WHEN SUBJECTED TO TEMPERATURES IN EXCESS OF 475°F.

4.3.4 NULL Control

To check the NULL control operation, proceed as follows:

a. Connect a piece of bare copper wire across the input terminals of the Model 365, and allow sufficient time for any heat generated in this process to dissipate.

b. Set the range selector to the 10 μV range.

c. Set the function switch to the NULL position.

d. Set the POLARITY switch to NORM.

e. Rotate the NULL control fully counterclockwise and note the meter indication.

f. Set the POLARITY switch to REV.

g. Rotate the NULL control fully counterclockwise and note the meter indication.

h. The indication obtained in steps e and g should be approximately equal and should be at least 5.

i. Rotate the control for an indication of 1. There will be considerable fluctuation in the indication at this point, caused by noise, thermal potentials, etc. Fluctuations of up to $\pm$0.3 μV may be considered normal.

4.3.5 Noise

The procedure for checking noise is as follows:

a. With the instrument completely warmed up, connect a 100 kΩ wirewound resistor across the input terminals of the Model 365, and shield to avoid spurious pickup. The resistor employed should use an alloy which has a low thermal potential against copper; Evanohm alloy is recommended.

b. Set the range selector to the 10 μV range.

c. Set the function switch to the NULL position.

d. Rotate the NULL control for an indication of 1.5 μV.

e. Note the fluctuation in indication; these should not exceed $\pm$0.3 μV.

The noise level is of course of greatest importance when making low level measurements. If the instrument is being used only at the higher levels, the acceptable noise level may be considerably higher than indicated above. A simple check of whether the level is acceptable is to actually measure a stable, noise-free, dc signal of the lowest level of interest and note the fluctuation, if any, in the indication. For example, a noise level of 2 or 3 μV would have little effect on indications above 1 mV.

If the noise level is found to be excessive, all components in the input section up to and including V1 may be suspected.

4.3.6 Range Switching

To check the range switching accuracy, proceed as follows:

a. Check the adjustment of the NULL control as outlined in Section 2.3.1.

b. Set the range selector to 100 V.

c. Connect a stable, low-resistance dc source to the input terminals of the Model 365.

d. Adjust the amplitude of the dc source for an indication of precisely 10 on the Model 365.

e. Reduce the output voltage of the dc source by precise factors of 10, while correspondingly reducing the range selector setting of the Model 365, noting any departures in indication from 10. Upon leaving the factory the acceptable errors in this check for the various ranges are:

Range	Error
1 kV	±0.15%
100 V	reference
10 V	±0.15%
1 V	±0.15%
100 mV	±0.15%
10 mV	±0.15%
1 mV	±1.00%
100 μV	±5.00%
10 μV	±5.00%, ±0.5 μV

The value for the 1000 V range is obtained with the same input as in step d above but the indication is noted at 1 on the indicator. For the value to be meaningful, the Scale Adjustment as outlined in Section 4.3.1 must be made prior to this check.

If the Ballantine Model 421 is used as the dc source above, the 10 μV signal should be obtained by placing an accurate 10:1 resistive divider across the 100 μV output. The resistance of this divider should be greater than 100 but less than 10,000 Ω to avoid loading errors. The resistors should employ an alloy which has a low thermal potential against copper. Evanohm or manganin are satisfactory.

If the ranging errors noted are significantly larger than those indicated above, the difficulty may be in one or more of the three attenuators used — input, mid-section or feedback. Table III in Section 3 is a listing of the total attenuation on any given range, as well as the amount of attenuation contributed by each attenuator. With this information it should be possible to localize the attenuator, if not the actual resistor responsible for error.

4.3.7 Amplifier Output Adjustment

To check the dc output, proceed as follows:

a. Set the Model 365 range selector to any range above 1 mV.

b. Set the function switch to METER.

c. Connect a stable, accurate, low-resistance source of dc to the input of the Model 365.

d. Adjust the output of the dc source to a level corresponding to full scale for the range selected on the Model 365, e.g., 10 V for the 10 V range.

e. Connect an accurate dc indicator to the output jack of the Model 365. The resistance of this device should be such as to not cause appreciable loading on 1650 Ω; 1 MΩ or greater would be satisfactory.

f. The indication should be 1.0 V ±1%.

g. The output, if incorrect, may be adjusted by means of R87. (See Fig. 5.)

h. Reduce the amplitude of the dc source by a precise factor of 10.

i. The indication should now be 0.1 V ±1%. There is no control for correcting this output. If it is found to be outside the limit specified, it is a good indication that trouble exists in the instrument, such as weak or shorted amplifier tubes, defective modulator-demodulator, etc.

4.3.8 Stability with Line Voltage

A simple check on the overall health of the instrument may be made by checking the indication stability vs. line voltage. A check of this sort is not intended, however, to replace the checks in the preceding section. To make this check, proceed as follows:

a. Set the range selector of the Model 365 to 10 mV.

b. Set the function switch to CAL, and adjust the CAL 10 control for an indication of precisely 10, with a line voltage of 115 V.

c. Set the line voltage to 105 V and note the change in indication.

d. Set the line voltage to 125 V and note the change in indication.

When the instrument leaves the factory the changes noted for steps c and d above are considerably less than ±0.25%. If changes significantly larger than this are noted two major items may be suspected, as follows:

a. Chopper supply voltage or tuning (see Section 4.3.11).

b. Amplifier vacuum tubes; all tubes should be checked on a reliable tube tester and those exhibiting low gm, shorts, etc., should be replaced.

4.3.9 Calibration Source

To check the internal calibration source, proceed as follows:

a. Check and adjust, if necessary, the sensitivity of this instrument as outlined in Section 4.3.2.

b. Set the range selector to 10 mV, and the function switch to CAL.

c. The indication should be precisely 10. If not, adjust R112 (see Fig. 5) for an indication of 10.

It should be noted from the above that the internal calibration source is not necessarily adjusted for an output of 10 mV, but rather to an indication of 10 on the 10 mV range. In this way the distribution of the inherent indicator errors achieved by the sensitivity adjustment as outlined in Section 4.3.2 is retained, whenever the internal calibration source is employed to calibrate the instrument.

4.3.10 120 c Hum Adjustment

To make the 120 c hum adjustment, proceed as follows:

a. Make the NULL adjustment as outlined in Section 2.3.1, employing a 100 kΩ resistor across the input terminals rather than a short circuit. The input terminals as well as the resistor should be shielded from spurious pickup.

b. Disconnect the blue lead running from the plate (pin 5) of V6.

c. Connect a sensitive, selective, ac voltmeter to the plate (pin 5) of V6.

d. Set the voltmeter so that it is selective at 120 c.

e. Adjust R100 (see Fig. 6) for minimum indication on the voltmeter.

f. Remove voltmeter connection, and restore the blue lead disconnected in step b.

The nature of this adjustment is such that it should seldom if ever require readjustment. It is recommended that if the equipment required for this adjustment is not available, R100 be left at its factory adjustment.

4.3.11 Chopper Supply Adjustments

There are two adjustments associcated with the chopper supply, a symmetry and frequency adjustment. To adjust these, proceed as follows:

a. Set the Model 365 range selector to 10 mV.

b. Set the Model 365 function switch to the CAL position.

c. Connect a dc voltmeter of the differential type to the dc output (see Fig. 5).

d. Set the range of the differential voltmeter so that changes in output of 0.01% may be recognized.

e. Adjust the line voltage supplied to the Model 365 to 105 V.

f. Adjust both R90 (see Fig. 6) Symmetry Adjust and R91 (see Fig. 5) Frequency Adjust for maximum dc output and repeat.

g. Note the output indication, raise the line supply to the Model 365 to 125 V, and again note the output. This change in output should not exceed 0.25%; typically it is less than 0.1% when the instrument is new.

Factors other than the chopper supply adjustment which may contribute to the stability of indication in line voltage are all amplifier tubes, high voltage rectifier tube, and the gaseous regulator tubes.

4.3.12 Input Circuit Overload Protection

To check the input circuit overload protection, proceed as follows:

a. With the Model 365 non-operating, connect a high-resistance, dc voltmeter across gaseous tube V9 located on the component board mounted on the range selector.

b. Connect a source of 200 V to the input terminals of the Model 365.

c. Gaseous tube V9 should ignite and the dc voltmeter should read approximately 70 V.

d. Disconnect the dc voltmeter from V9 and reconnect across diodes CR1 and CR2 (input to chopper). The voltage measured here should not exceed 12 V.

If the results indicated above are not obtained, replace gaseous tube V9 or diodes CR1 and CR2 as necessary.

4.3.13 Ammeter Accuracy

To check the accuracy of the current measuring ranges on the Model 365, proceed as follows:

a. Make the NULL adjustment as outlined in Setion 2.3.3.

b. Connect a stable, accurate, high impedance source of current to the input terminals of the Model 365. For zero error, the source would have to have an infinite resistance. However, a source resistance of 1,000 times the input resistance of the Model 365 causes only 0.1% error, while 100 times causes 1% error.

c. Set the current source to values corresponding to the full scale value for each range of the Model 365 and note any indication errors. These errors should be within the following limits:

Range	Error
1 A	±2%
100 mA	±2%
10 mA	±2%
1 mA	±2%
100 μA	±2%
10 μA	±2%
1 μA	±2%
100 nA	±5%
10 nA	±5%

When the instrument leaves the factory the errors noted are substantially smaller than indicated above. If larger errors exist, and voltmeter operation is normal, resistors R5, R6, R7, R8, R9, and R10 may be defective. Most of these are simply checked by measuring the input resistance on the various ammeter ranges. The resistors should be within ±1% of their nominal values. It may not be possible to obtain accurate measurements on R9 and R10 because of internal lead and switch resistances. For greatest accuracy measure these units internally.

4.3.14 Chopper Replacement

If it has been determined that the chopper needs replacement, the procedure is as follows:

a. Remove the instrument case.

b. Disconnect the six leads running from the base of the chopper; three of these leads are bare copper, three are plastic-coated and tightly twisted. Note the connection for each lead before removing.

c. Remove the 7 pin top-connector from the top of the chopper.

d. Remove the 2 screws which secure the chopper base to the chassis.

e. The chopper may now be removed from the instrument.

f. Install the new chopper, observing the reverse of the procedure above.

5. SERVICING AND TROUBLESHOOTING

In case of voltmeter malfunction, limited servicing by the user is feasible provided skilled personnel and recommended equipment are available, and the procedures outlined in this and Section 4 are followed. It should be mentioned that the procedures in this manual are of a simplified nature. Refined and comprehensive service and calibration require specialized equipment which may not be available to the user. Therefore, if this is the case, or if trouble develops which cannot be corrected by the procedures outlined here, or when a most accurate calibration is desired, it is recommended that the instrument be returned to Ballantine Laboratories, Inc. The instrument should in all cases be preceded by a letter stating the nature of the trouble or the desired service. (See Section 6 for shipping instructions.)

5.1 Equipment Required

a. A stable, accurate, low-resistance source of dc covering a range of 100 μV to 100 V. The Ballantine Model 421 is recommended.

b. A stable, accurate, dc indicator (preferably of the differential type) covering a range of at least 0.1 V to 500 V.

c. An ohmmeter covering a range of at least 0 to 100 MΩ.

d. Sensitive, accurate, high-impedance, ac voltmeter with a voltage range of at least 1 mV to 500 V, and a frequency range of at least 30 c to 1000 c. The Ballantine Models 300E, 300G, 300H, 310, 314, or 320 are recommended.

5.2 General Instructions

When there is malfunction that is not simply corrected by any of the normal calibration adjustments (see Section 4), the following procedure is recommended.

a. Check all tubes on a reliable tube tester; replace any which exhibit low gm, shorts, grid current, etc.

b. If tube replacement does not restore normal operation, check all dc and ac operating potential and compare with those listed on the schematic (Fig. 7) located at the rear of the manual. An abnormal voltage may give a clue to the nature of the defect.

c. If neither step a nor step b indicates the nature of the difficulty, make a thorough physical examination for broken or discolored components, broken leads, defective connections, etc.

5.3 Signal Tracing

If the simple checks outlined in Section 5.3 fail to reveal the cause of malfunction, recourse may be had to signal tracing. To trace the signal, proceed as follows:

a. Set the range selector of the Model 365 to the 10 mV range.

b. If the internal CAL source is known to be operating properly, rotate the function switch to the CAL position. If there is any doubt about the CAL source, rotate the function switch to the METER position, and connect a stable dc source of 10 mV to the input terminals.

c. With a sensitive, accurate, high-impedance ac voltmeter, check the ac signal potentials and compare with those (labelled 94 c) on the schematic (Fig. 7) located at the end of this manual. Any radical difference from those indicated may provide a clue to the difficulty.

5.4 Troubleshooting Chart

To assist in troubleshooting, a chart has been prepared which lists symptoms, possible causes, and/or remedy, and where possible, pertinent section of this manual.

Symptom	Possible Cause and/or Remedy	Pertinent Sections
Instrument inoperative	No power; fuse blown	4.1.1
Pilot light does not light	Defective power supply	3.9
Instrument indication with no input	Function switch in NULL position	2.3
	NULL control improperly adjusted	2.3
	Noisy input tube V1	4.3.5
	Defective chopper	4.3.14

Trouble Shooting Chart (Continued)		
Symptom	**Possible Cause and/or Remedy**	**Pertinent Sections**
Instrument apparently operating but no indication	POLARITY switch in wrong position or defective	2.5
	Defective chopper	3.7
	C42 shorted	3.7
Voltmeter indications in error	Sensitivity misadjusted	4.3.2
	NULL control improperly adjusted	2.3
	Defective tube	
	Defective chopper	3.3, 3.7
	Defective attenuator	3.1
	Defective C42	3.7
	Defective meter	
	Defective R23	4.3.2
Voltmeter indication normal, one or more ammeter ranges in error	NULL control improperly adjusted	2.3.3, 2.3.4
	Defective resistor R5, R6, R7, R8, R9, R10	3.1, 4.3.13
Excessive drift on most sensitive range	Instrument in warm or drafty location	
	Defective input component	
Excessive change in indication with line voltage change	Weak or defective tubes	
	Chopper supply improperly adjusted	4.3.11
	Chopper drive voltage low	
Indication normal, dc output low or absent	C43 defective or shorted	3.7
	Defective resistor R86, R87	3.7
Calibration voltages incorrect; not possible to correct by R112	Defective resistor R110, R111, R112, R113	3.8
	Defective tube V8228	3.8
Instrument operative, NULL indication incorrect	Defective CR11, B1	
	Resistor R80, R83, R85 defective	3.7
CAL 10 operative, CAL 1 inoperative	Defective battery B1	3.7
	Defective R80, R81, R82, R83	
	Defective switch S2C	
Chopper supply frequency incorrect; not possible to correct with R91	Defective resistor R90, R91, R92, R93	3.9, 4.3.11
	Defective capacitor C50, C51	3.9
	Defective chopper G	3.13
	Defective transistor Q1, Q2	3.9

6. SHIPPING INSTRUCTIONS

If it should be necessary to return the instrument to Ballantine Laboratories, Inc., make certain that at least four inches of packing material surrounds the instrument to prevent damage during shipment. Ship via REA Express, motor truck, or air freight, to

Ballantine Laboratories, Inc.
90 Fanny Road
Boonton, New Jersey 07005

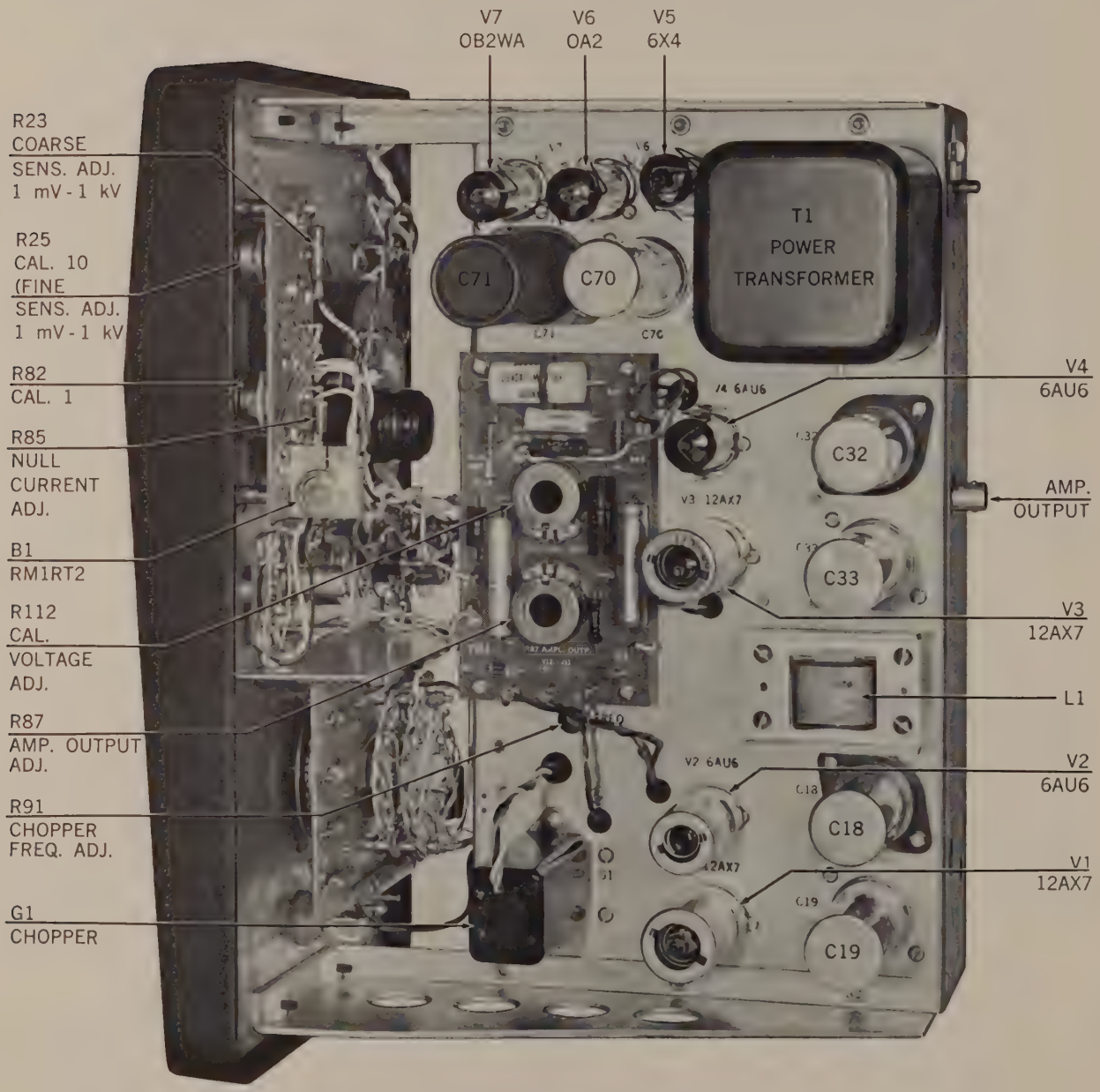


Fig. 5. Side View (right) of Model 365, showing Locations of Tubes and Adjustments

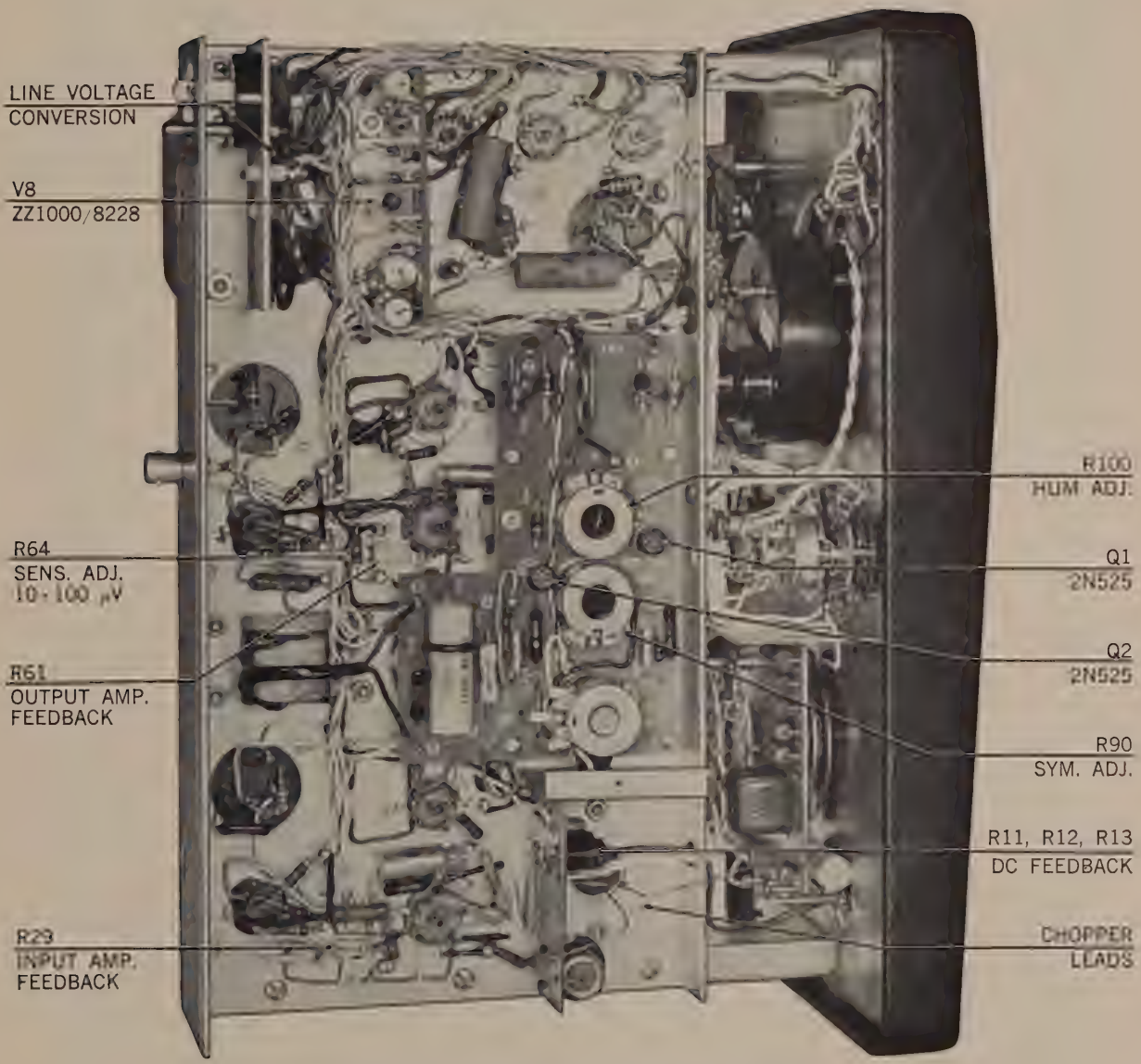


Fig. 6. Side View (left) of Model 365, showing Locations of Tubes and Adjustments

7. REPLACEMENT PARTS LIST

REFER TO MODEL 365 CIRCUIT DIAGRAM, DWG. ME-2631B

B. L. Part No.	*Circuit Symbol*	*Capacitors*	*Manufacturer*
2246	C1	1,500 pF, 20%, Type CCD-152, 1 kV	Arco
2363	C2	0.1 μF, 5%, Type 148P10456, 600 V	Sprague
8102	C10	0.33 μF, 20%, Type 602, 50 V	Goodall
8102	C11	0.33 μF, 20%, Type 602, 50 V	Goodall
2246	C12	1,500 pF, 20%, Type CCD-152, 1 kV	Arco
2393	C13	0.1 μF, 5%, Type 114P1045R5S4, 50 V	Sprague
2395	C14	0.01 μF, 5%, Type 148P10354, 400 V	Sprague
2386	C15	1,500 pF, 5%, Type 192P15252, 200 V	Sprague
2273	C16	250 pF, 5%, Type DM-15-251-J, 500 V	Arco
2367	C17	0.1 μF, 5%, Type 148P10452, 200 V	Sprague
2780	C18A	500 μF, −10%, +150%, Type DFP, 20 V	Sprague
	C18B	200 μF, −10%, +150%, Type DFP, 20 V	Sprague
2042	C19A	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
	C19B	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
	C19C	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
2387	C20	820 pF, 5%, Type 192P82152, 200 V	Sprague
2781	C21	250 μF, −10%, +75%, Type 30D117A1, 3 V	Sprague
2389	C22	0.56 μF, 5%, Type 148P56452, 200 V	Sprague
2364	C23	.033 μF, 5%, Type 148P33352, 200 V	Sprague
2386	C30	1,500 pF, 5%, Type 192P15252, 200 V	Sprague
2367	C31	0.1 μF, 5%, Type 148P10452, 200 V	Sprague
2788	C32A	20 μF, −10%, +250%, Type DFP, 10 V	Sprague
	C32B	100 μF, −10%, +250%, Type DFP, 10 V	Sprague
2042	C33A	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
	C33B	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
	C33C	50 μF, −10%, +100%, Type DFP, 150 V	Sprague
2386	C34	1,500 pF, 5%, Type 192P15252, 200 V	Sprague
2784	C35	25 μF, −10%, +75%, Type 30D110A1, 3 V	Sprague
2392	C40	0.47 pF, 5%, Type 148P47452, 200 V	Sprague
2367	C41	0.1 μF, 5%, Type 148P10452, 200 V	Sprague
7804	C42	250 μF, −10%, +100%, Type 40D257F003DH4, 3 V	Sprague
7804	C43	250 μF, −10%, +100%, Type 40D257F003DH4, 3 V	Sprague
7808	C44	25 μF, −10%, +75%, Type 40D256G003BB4	Sprague
2785	C50	6.8 μF, 10%, Type 150D685X9035B2, 35 V	Sprague
2785	C51	6.8 μF, 10%, Type 150D685X9035B2, 35 V	Sprague
2543	C60	1,500 pF, −20%, +80%, Type 878, 3 kV	Erie
2543	C61	1,500 pF, −20%, +80%, Type 878, 3 kV	Erie
2543	C62	1,500 pF, −20%, +80%, Type 878, 3 kV	Erie
2543	C63	1,500 pF, −20%, +80%, Type 878, 3 kV	Erie
2789	C70A	10 μF, −10%, +50%, Type DFP, 500 V	Sprague
	C70B	10 μF, −10%, +50%, Type DFP, 500 V	Sprague
	C70C	50 μF, −10%, +50%, Type DFP, 150 V	Sprague
2756	C71A	1,000 μF, −10%, +150%, Type DFP, 15 V	Sprague
	C71B	1,000 μF, −10%, +150%, Type DFP, 15 V	Sprague
2367	C72	0.1 μF, 5%, Type 148P10452, 200 V	Sprague
2084	C73	300 μF, −10%, +75%, Type 30D118A1, 3 V	Sprague

REPLACEMENT PARTS LIST *(Continued)*

REFER TO MODEL 365 CIRCUIT DIAGRAM, DWG. ME-2631B

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
2629	R1[1]	9,900,000 ohms, 1%, Type PT-70N	Pyrofilm
2630	R2[1]	91,000 ohms, 1%, Type PT-500	Pyrofilm
2631	R3[1]	9,010 ohms, 1%, Type PT-500	Pyrofilm
2697	R4[1]	1,000 ohms, 1%, Type PT-500	Pyrofilm
1324	R5	10,000 ohms, 1%, Type CPX ½	Aerovox
1338	R6	1,000 ohms, 1%, Type CPX ½	Aerovox
1355	R7	100 ohms, 1%, Type CPX ½	Aerovox
2685	R8	10 ohms, 1%, Type CPX ½	Aerovox
1887	R9	1 ohm , 1%, Type M59	Mepco
1890	R10	.097 ohm , 1%, Type M61	Mepco
1885	R11[2]	1.56 ohms, 1%, Type MPC 200	Mepco
1884	R12[2]	14.04 ohms, 1%, Type MPC 200	Mepco
1883	R13[2]	140.40 ohms, 1%, Type MPC 200	Mepco
1507	R20	150,000 ohms, 1%, Type CPX-2	Aerovox
1307	R21	150,000 ohms, 1%, Type CPX ½	Aerovox
1124	R22	15,000,000 ohms, 5%, Type EB	Allen-Bradley
1327	*R23	5,000 ohms, 1%, Type CPX ½	Aerovox
1330	R24	3,000 ohms, 1%, Type CPX ½	Aerovox
1945	R25	10,000 ohms, 30%, Type UPM 45	CTS
2745	R26	1,000,000 ohms, 1%, Type MF6C ¼-TO	Electra
1075	R27	27 ohms, 5%, Type EB	Allen-Bradley
7228	R28	25,000 ohms, 1%, Type N20	Corning
1782	R29	7.15 ohms, 1%, Special	Ballantine
1039	R30	22,000 ohms, 5%, Type EB	Allen-Bradley
2744	R31	500,000 ohms, 1%, Type MF6C ¼-TO	Electra
7253	R32	1,550,000 ohms, 1%, Type MF7C	Electra
7228	R33	25,000 ohms, 1%, Type N20	Corning
2618	R34	500,000 ohms, 1%, Type CPX ½	Aerovox
1048	R35	4,700 ohms, 5%, Type EB	Allen-Bradley
7253	R36	1,550,000 ohms, 1%, Type MF7C	Electra
1065	R37	200 ohms, 5%, Type EB	Allen-Bradley
7226	R38	301 ohms, 1%, Type N20	Corning
1062	R39	390 ohms, 5%, Type EB	Allen-Bradley
1048	R40	4,700 ohms, 5%, Type EB	Allen-Bradley
1300	R50[3]	1,000,000 ohms, 1%, Type CPX ½	Aerovox
1309	R51[3]	100,000 ohms, 1%, Type CPX ½	Aerovox
1324	R52[3]	10,000 ohms, 1%, Type CPX ½	Aerovox
2628	R53[3]	1,111 ohms, 1%, Type CPX ½	Aerovox

[1] Part of a matched set — must be purchased as Set No. 1567.

[2] Part of a matched set — must be purchased as Set No. 1565.

[3] Part of a matched set — must be purchased as Set No. 1566.

* Calibration Item — In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST *(Continued)*

REFER TO MODEL 365 CIRCUIT DIAGRAM, DWG. ME-2631B

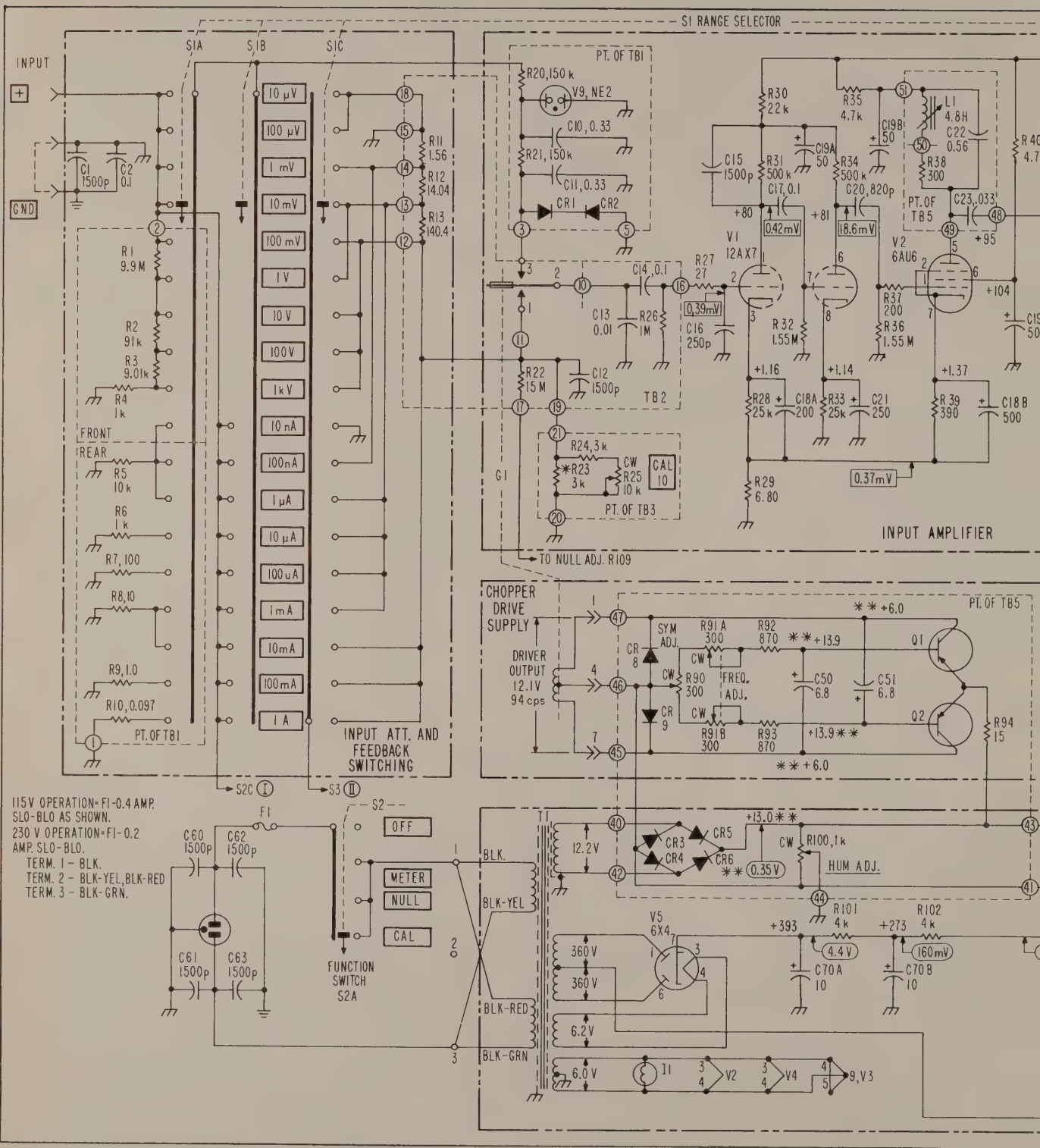
B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1116	R60	24,000 ohms, 5%, Type EB	Allen-Bradley
1779	R61	2.66 ohms, 1%, Special	Ballantine
1026	R62	100,000 ohms, 5%, Type EB	Allen-Bradley
1300	R63	1,000,000 ohms, 1%, Type CPX ½	Aerovox
1128	*R64	110 ohms, 5%, Type EB	Allen-Bradley
1007	R65	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1116	R66	24,000 ohms, 5%, Type EB	Allen-Bradley
1026	R67	100,000 ohms, 5%, Type EB	Allen-Bradley
1010	R68	1,000,000 ohms, 5%, Type EB	Allen-Bradley
1007	R69	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1065	R70	200 ohms, 5%, Type EB	Allen-Bradley
1063	R71	300 ohms, 5%, Type EB	Allen-Bradley
1680	R72	20,000 ohms, 1%, Type N-20	Corning
1042	R73	15,000 ohms, 5%, Type EB	Allen-Bradley
1081	R80	27,000 ohms, 5%, Type EB	Allen-Bradley
1024	R81	150,000 ohms, 5%, Type EB	Allen-Bradley
1944	R82	50,000 ohms, 10%, Type UPM 45	CTS
1081	R83	27,000 ohms, 5%, Type EB	Allen-Bradley
1061	R84	510 ohms, 5%, Type EB	Allen-Bradley
1060	*R85	620 ohms, 5%, Type EB	Allen-Bradley
1657	R86	1,500 ohms, 1%, Type N-20	Corning
1940	R87	300 ohms, 30%, Type UPM 45	CTS
1057	R88	1,000 ohms, 5%, Type EB	Allen-Bradley
1940	R90	300 ohms, 30%, Type UPM 45	CTS
1941	R91	300/300 ohms, 30%, Type P-U45-V45	CTS
1668	R92	750 ohms, 1%, Type N-20	Corning
1668	R93	750 ohms, 1%, Type N-20	Corning
1101	R94	15 ohms, 5%, Type EB	Allen-Bradley
1939	R100	1,000 ohms, 30%, Type UPM 45	CTS
1876	R101	4,000 ohms, 5%, Type 454 E 4025	Sprague
1876	R102	4,000 ohms, 5%, Type 454 E 4025	Sprague
1886	R103	3.6 ohms, 5%, Type BWH	IRC
1054	R104	2,000 ohms, 5%, Type EB	Allen-Bradley
1054	R105	2,000 ohms, 5%, Type EB	Allen-Bradley
1024	R106	150,000 ohms, 5%, Type EB	Allen-Bradley
1135	R107	910 ohms, 5%, Type EB	Allen-Bradley
1039	R108	22,000 ohms, 5%, Type EB	Allen-Bradley
1938	R109	10,000 ohms, 30%, Type UPM 45	CTS
1327	*R110	5,000 ohms, 1%, Type CPX ½	Aerovox
1881	R111	355,800 ohms, 1%, Type M57	Mepco
1946	R112	7,500 ohms, 30%, Type UPM 45	CTS
1889	R113	45 ohms, 1%, Type M60	Mepco

* Calibration Item — In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST *(Continued)*

REFER TO MODEL 365 CIRCUIT DIAGRAM, DWG. ME-2631B

B. L. Part No.	*Circuit Symbol*	*Other Components*	*Manufacturer*
3096	B1	Battery, Type RM1RT, 1.35 V	Mallory
7904	CR1, 2	Diode, Zener, Type 1N961A	Hoffmann
5579	CR3, 4, 5, 6, 7	Rectifier, Type 1N1692	Transitron
5588	CR8, 9	Diode, Type 1N816, Special	Ballantine
3410	F1	Fuse, 0.4 A, Type MDL Slo-Blo	Bussmann
3088	G1	Chopper, Special	Ballantine
3475	I1	Pilot Light, Type 1815	General Electric
3072	L1	Coil, Special	Ballantine
6008	M1	Meter, Special	Ballantine
3295	S1	Switch, Range Selector, Special	Ballantine
3282	S2	Switch, Function, Special	Ballantine
3296	S3	Switch, Polarity Selector, Special	Ballantine
3059	T1	Transformer, Power	Ballantine
5596	Q1, 2	Transistor, Type 2N525	General Electric
3140	V1, 3	Tube, Type 12AX7	Amperex
7907	V2, 4	Tube, Type 6AU6A, Code 16	RCA
3105	V5	Tube, Type 6X4	RCA
3106	V6	Tube, Type OA2	RCA
5578	V7	Tube, Type OB2WA	Tung-Sol
7903	V8	Tube, Type ZZ 1000/8228	Amperex
3138	V9, 10, 11, 12	Tube, Type NE-2	General Electric


S1 RANGE SELECTOR
S1A
S1B
S1C
INPUT
GND
C1 1500p
C2 0.1
R1 9.9M
R2 91k
R3 9.01k
R4 1k
FRONT
REAR
R5 10k
R6 1k
R7, 100
R8, 10
R9, 1.0
R10, 0.097
PT. OF TB1
10 µV
100 µV
1 mV
10 mV
100 mV
1 V
10 V
100 V
1 kV
10 nA
100 nA
1 µA
10 µA
100 uA
1 mA
10 mA
100 mA
1 A
R11 1.56
R12 14.04
R13 140.4
INPUT ATT. AND FEEDBACK SWITCHING
PT. OF TB1
R20, 150 k
V9, NE2
C10, 0.33
R21, 150k
C11, 0.33
CR1
CR2
C14, 0.1
C13 0.01
R26 1M
R22 15 M
C12 1500p
TB2
R24, 3 k
R23 3k
CW R25 10 k
CAL 10
PT. OF TB3
G1
TO NULL ADJ. R109
R27 27
0.39mV
C16 250p
V1 12AX7
R30 22k
R31 500 k
C15 1500p
C17, 0.1
C19A 50
R34 500 k
C20, 820p
R35 4.7k
C19B 150
L1 4.8H
C22 0.56
R38 300
PT. OF TB5
C23, 033
+80
+81
0.42mV
18.6mV
+95
V2 6AU6
R37 200
R36 1.55 M
R32 1.55M
+104
+1.16
+1.14
+1.37
R28 25k
C18A 200
R33 25k
C21 250
R 39 390
C18B 500
R29 6.80
0.37mV
INPUT AMPLIFIER
CHOPPER DRIVE SUPPLY
DRIVER OUTPUT 12.1V 94 cps
SYM ADJ.
R91A 300
R92 870
R90 300
FREQ. ADJ.
R91B 300
R93 870
CR8
CR9
C50 6.8
C51 6.8
+6.0
+13.9
+13.9
+6.0
Q1
Q2
R94 15
PT. OF TB5
115V OPERATION=F1-0.4 AMP. SLO-BLO AS SHOWN.
230 V OPERATION=F1-0.2 AMP. SLO-BLO.
TERM. 1 - BLK.
TERM. 2 - BLK-YEL, BLK-RED
TERM. 3 - BLK-GRN.
F1
C60 1500p
C62 1500p
C61 1500p
C63 1500p
S2C
S3
S2
OFF
METER
NULL
CAL
FUNCTION SWITCH S2A
BLK.
BLK-YEL
BLK-RED
BLK-GRN
T1
12.2V
360 V
360 V
6.2V
6.0 V
I1
V2
V4
9, V3
CR3
CR4
CR5
CR6
+13.0
0.35V
R100, 1k
HUM ADJ.
V5 6X4
R101 4k
R102 4k
+393
+273
4.4V
160mV
C70A 10
C70B 10

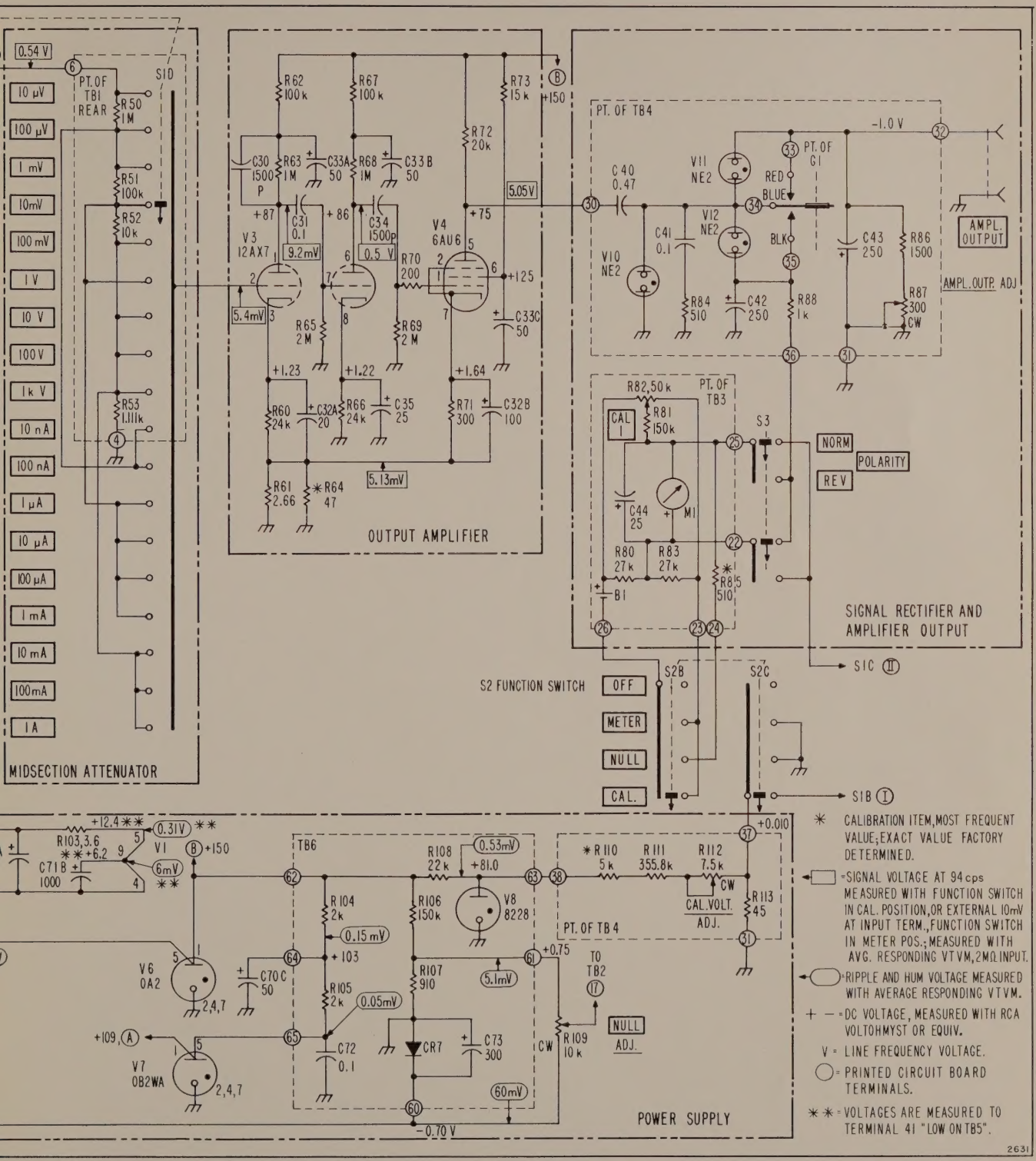


Fig. 7. Schematic of Model 365 Sensitive DC Volt/Ammeter

Drawing No. ME-2631B

BALLANTINE LABORATORIES, INC.

Boonton, N. J.

MP MASTER
MA31981